Modeling Damage and Failure in Composite Flyer Impact Experiments

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This work presents the predicted results of three composite flyer experiments using a model based upon the Gurson-Tvergaard-Needleman approach to representing the void growth process. Overall the results compare reasonably well with experiment, although work is necessary in bringing a material length scale into the constitutive model to deal with mesh sensitivity issues and a physically based void nucleation model. These issues are currently being addressed.

The dynamic damage and failure response of metallic materials is a complex process of physical events that begins at very small length scales and grows in severity to complete material separation. This process is heavily influenced by the loading profile experienced by the material. In this brief study, we model three different loading profiles through the use of three different composite flyer geometries. Bourne and Gray [1] performed these experiments on annealed Department of Defense (DoD) tantalum (Ta) using composite flyer configurations to change the velocity-time profile experienced by the sample while maintaining a constant pull-back magnitude. Figure 1 is a schematic representation of the experimental configuration used for all three shots. The thickness of the sample layer was 4.571 mm while the overall thickness of the composite flyers were 2.286 mm. The diameter of the assemblies was 57.15 mm while the nominal diameter of the sample was 19.672 mm. The velocities and flyer configurations are given in Table 1.

The strain rate and temperature sensitivity of the plastic deformation response is represented through the flow stress. The deformation of tantalum at the rates observed here has been shown to be well represented by several models, which are based upon thermal activation kinetics developed by Kocks et al. [2]. Here we employ the isotropic mechanical threshold strength (MTS) model, which has been well established for tantalum. The MTS model is based on the concept of a superposition of resistances to the glide of dislocations. Generally they are grouped as athermal barriers (e.g., grain boundaries) and thermally influenced barriers (e.g., Peierls stress – intrinsic lattice resistance, forest dislocations, dislocation structure, solute atoms). The mechanical threshold strength is the deformation resistance at 0 K. The flow stress used here is that stress adjusted to current temperature and strain rate. The three experiments described above were modeled using EPIC06 in 2D.

Results for the Ta-Ta configuration are given in Fig. 2, with a flyer velocity of 249 m/s. These results demonstrate a rather substantial mesh sensitivity, which does not converge until reaching a cell size of 23 microns. At a 23-micron mesh resolution the simulation results compare reasonably well with the experimental free-surface velocity curve. The deformed mesh at a mesh resolution of 23 microns at a time of 15 microseconds is given in Fig. 3, which suggests a substantial damage and failure region. Although there exists a length scale in the constitutive model associated with the overstress model, it is still inadequate in resolving the mesh sensitivity issue. Results for the Cu-W (copper-tungsten) flyer configuration are given in Fig. 3 – flyer velocity of 616 m/s. The results compare favorably with the experiments at a resolution of 76-micron cell size. The deformed mesh in Fig. 3 predicts that complete failure has occurred. Results for the Ta-Al (tantalum-aluminum) flyer configuration are given in Fig. 4 at a flyer velocity of 350 m/s. The results compare reasonably well with those from the experiment, although the model does not predict the complex wave profile immediately after the initial pull-back. The deformed mesh predicts that we do not achieve complete failure of the material and so this experiment is likely well within the nucleation phase of damage progression – something that is not yet explicitly modeled in this work.

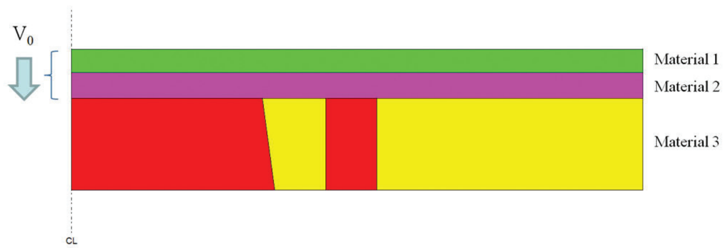

Fig. 1. Schematic representation of the experimental configuration using the velocities and flyer configurations given in Table 1.

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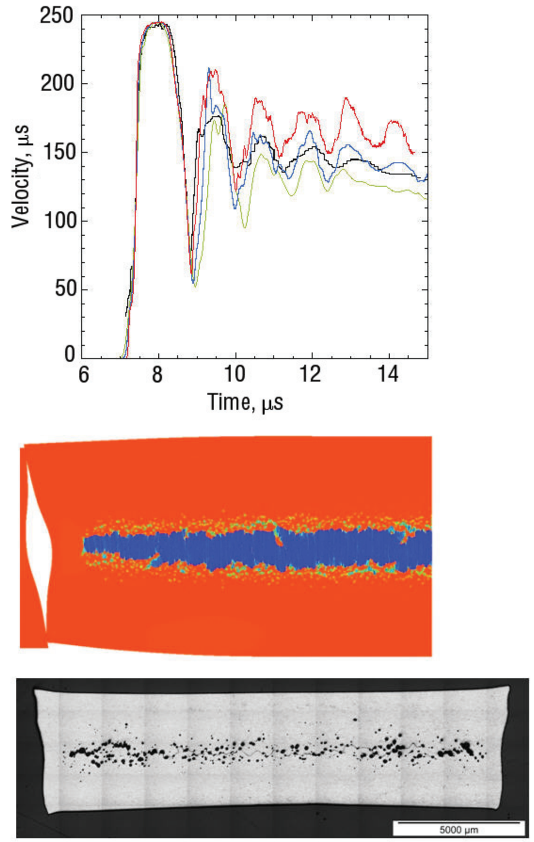

Fig. 2. Results for the Ta-Ta configuration.

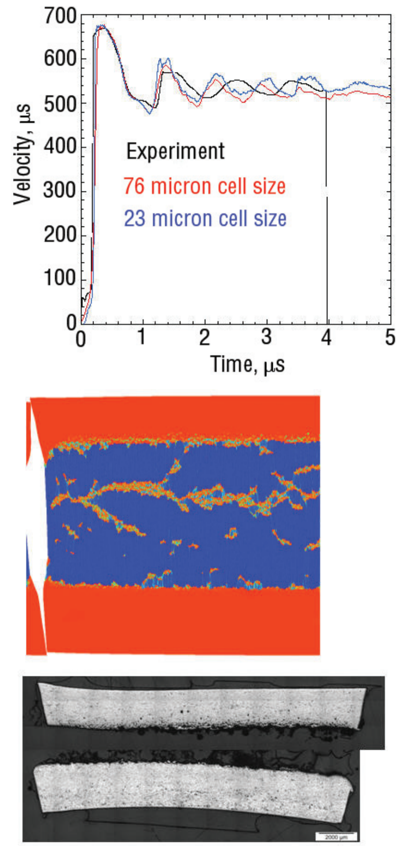

Fig. 3. The deformed mesh at a mesh resolution of 23 microns at a time of 15 microseconds.

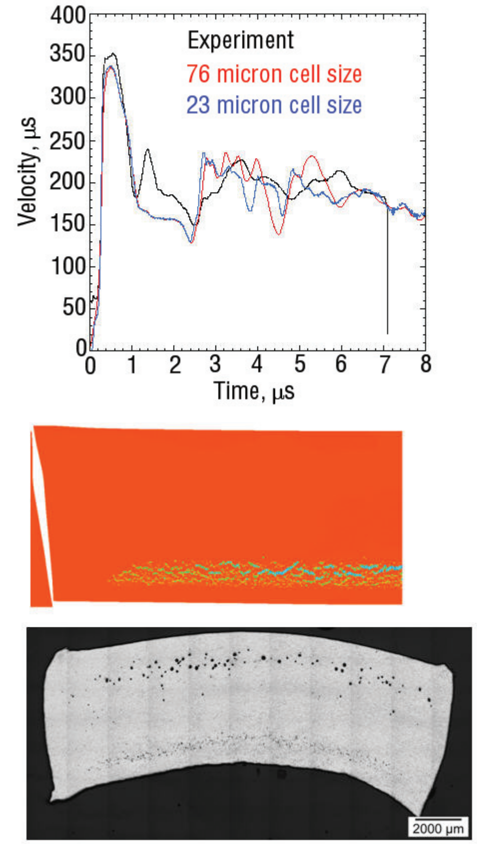

Fig. 4. Results for the Ta-Al flyer configuration.

Table 1. Details of experimental configuration for Fig. 1.

V0, m/s	249	616	350
Material 1	Ta	Cu	Ta
Material 2	Ta	W	Al
Material 3	Ta	Ta	Ta

[1] Bourne and Gray, unpublished results
[2] Kocks, U.F., et al., *Thermodynamics and Kinetics of Slip, Progress in Materials Science,* Pergamon Press, NY (1975).

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